GOVERNOR'S DROUGHT TASK FORCE
IRRIGATED AGRICULTURE WORK GROUP

final draft report – summary version

for

public review and comment

August 25, 2004

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Forward

This document summarizes the much longer and more detailed Irrigated Agriculture Work Group Report to the Governor's Drought Management Task Force. Discussion, findings, and recommendations are based primarily on a survey of irrigation district managers. Other supporting data include interviews with members of Arizona's irrigated agriculture community, reports and papers submitted to the Work Group, a series of public meetings, and anecdotal information. Data and discussion relating to the Sulphur Springs Valley has been extracted from a recent University of Arizona Report. From all this detail, only summary data is included in this version of the Work Group Report. Readers wishing to learn the basis for the discussion, findings, and recommendations presented here are referred to the longer and more detailed full Work Group Report.

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Abstract

Irrigated Agriculture has a storied and important history in Arizona. Its economic viability must be sustained over the long-term. A 2003 survey of irrigation district managers and a variety of other methods were used to investigate vulnerability, impact, and adaptation to long-term drought in Arizona's irrigated agriculture.

Irrigated agriculture in Arizona primarily uses surface water from the Colorado River mainstem and CAP canal, surface water from other principal Arizona streams, and groundwater. Irrigation district supplies are mostly influenced by how many of these water sources are available, water volumes available by source, related surface water priorities, and related physical and hydrological limits on groundwater withdrawals. Vulnerability to drought is also a function of these variables. Because the variables critically differ between irrigation districts, each district's vulnerability to drought also differs. Using these variables, the Report proposes five classes of irrigation districts.

From the survey, chief vulnerabilities to drought in 2003 included reliance on a single source of water, inadequate storage, widely varying precipitation, and low supply reliability. Trends expected by 2005/06 included severe supply shortages, increased reliance on single supply sources, lack of drought planning and preparedness, and uncertain and more costly power supplies. The current drought has generated a pronounced trend toward increased agricultural reliance on groundwater by many growers and several districts. Longer-term this trend may associate with declining water tables, increased production costs, deteriorating water quality, and other vulnerabilities.

From the survey, leading impacts expected if the current drought does not improve included increased groundwater depletion and water table declines, increased energy demand and reduced supplies, income loss for both farmers and irrigation districts, fewer planted acres, lowered financial viability of districts, and reservoir and lake drawdown.

Looking at drought adaptation and response, the Report suggests a strategic focus on longer-term preparedness and the more important and tractable vulnerabilities revealed by the Work Group, particularly supply. The survey listed 27 drought preparedness and response items and divided them into the five categories of: Voluntary, market-driven water transfers (79% of managers responded positively); programs (78% positive response); planning and research (58% positive response); forecasting and early warning (54% positive); and agricultural water conservation (35% positive). The more popular individual survey items included: Create a drought property-tax credit program for farmers (83% positive response); guaranteed low-interest loans to drought-stricken farmers (83% positive); short-term, voluntary, market-driven water transfers (79% positive); investment program to increase the flexibility of water supply sources (78%); develop a State water plan (75%); develop criteria to trigger drought-related actions (65%); and improve the accuracy of seasonal runoff and water supply forecasts (65%).

The Report addresses Eastern and South Eastern Arizona, and Dairies and Feed Yards, in separate sections in each chapter.

I. Introduction And Background

Economic Importance of Arizona's Irrigated Agriculture

Agriculture has a long and storied history in Arizona. Historians report that the Hohokam civilization disappeared from the Salt River Valley in the mid-1450's after having lived and farmed in the Valley for more than a millennium. Domestic livestock was introduced into Arizona by Spanish settlers in the early 1500's. Modern day farming activity in the Salt River Valley dates back to 1868 when Jack Swilling first diverted water from the Salt River to irrigate 1,000 acres of farmland. (Gammage, *Phoenix in Perspective, 1999).* The farming and ranching industries have been a primary factor in Arizona's economic wellbeing for over 500 years, producing food and fiber for the citizens of Arizona, the United States, and for export to overseas markets. Today, the value added to the State economy, including primary production and the forward and backward economic linkages to it, is estimated at $6 to 7 billion dollars annually.

Objective of this Plan

The objective of the Irrigated Agriculture Work Group, consistent with the Executive Order authorizing it, is to

> Assess the vulnerabilities, risks and impacts of drought on Arizona's irrigated agriculture sector and develop response, mitigation and adaptation strategies to sustain the long-term economic viability of the State's irrigated agriculture in the event of protracted drought.

Commercial cattle feeding and dairy production operations are included here because these confined operations are impacted by drought more similarly to irrigated agriculture than range livestock (see Chapter II Annex, "Dairies and Feed Yards").

Drought and Irrigated Agriculture

Drought impacts agricultural water supplies and water demand. The extent of the impact can vary significantly from one irrigation district, or farmer, to another based on many factors. Agricultural water users are impacted by meteorological, hydrological and socioeconomic drought. As precipitation declines (meteorological drought), systems reliant primarily on surface water supplies will be impacted more immediately than groundwater dependent systems that draw on water supplies stored over thousands of years. Systems with deep wells in productive alluvial aquifers will be less impacted than systems with wells in fractured rock or near streams that experience widely fluctuating groundwater levels in response to climate conditions. This impact on supply from long periods of precipitation shortfall is referred to as hydrologic drought, which typically lags behind meteorological drought. In Arizona, hydrologic drought that occurred in past years or at great distances from irrigated agricultural areas can have profound impacts, because our surface water supplies often originate from surface storage or as precipitation over distant areas. Additionally, as groundwater levels or surface water supplies diminish, water quality can become a concern. In droughts, water demand typically increases as farmers apply more water to meet crop demand in response to increased temperatures which generally accompany drought. In cases where drought severely impacts agricultural water supplies, economic impacts may result at the irrigation district, at the farm, and in the community. These types of impacts are collectively called "socioeconomic drought".

Less water for delivery by irrigation districts impacts their revenue stream while increasing costs of system maintenance and the possibility of increased power costs as increased reliance on groundwater supplies is needed to replace surface water supplies where applicable. Farmers may face changes in cropping patterns and farm management methods that generally have negative impacts on farm income. Ultimately, severe drought conditions can lead to fallowing of irrigated land negatively impacting the financial well being of the farming operation. In acute situations there may be short term community impacts, less crop inputs purchased, and decreased use of farm labor. In chronic drought situations local communities with dependence upon production agriculture for their economic viability will be impacted.

Methods

The analysis, findings, and recommendations in the Irrigated Agriculture Work Group Report are based on a drought survey targeted at the irrigated agriculture community. The survey was developed in mid-2003 and distributed to 42 irrigation district managers statewide. By the end of 2003, twenty-two completed surveys had been received from irrigation districts located in Yuma, Yavapai, Maricopa, Pinal, and Pima counties, covering nearly every region of the state and accounting for an estimated 2,180,000 acre feet of water delivered to approximately 686,600 acres of farmland in each of the baseline years of 2000 and 2001.

The drought survey questions covered the general areas of:

- Irrigation District Water Supply Sources
- Drought Vulnerability
- Drought Impacts
- Drought Response, Mitigation and Adaptation

Additional sources of information included interviews with members of Arizona's irrigated agriculture community, reports and papers submitted to the Work Group, a series of public meetings, and numerous reports provided by irrigation water managers and producers at various 2004 forums addressing the impact of drought on Arizona's irrigated agriculture (see, for example, Chapter III Annex, "Impact of the Drought on the San Carlos Irrigation District").

The survey, and therefore the most important findings and recommendations, represent a snapshot in time, late 2003. The drought has worsened since then, and several Work Group representatives have stated that survey responses might differ today.

Eastern and South Eastern Arizona

For purposes of this report, areas in Eastern and South Eastern Arizona will be discussed under separate subheadings in each chapter. Geographically, this discussion covers the Upper Gila – Safford Valley area, as well as the Sulphur Springs Valley, that is, agricultural areas lying along a line roughly connecting Bonita, Wilcox, and Douglas. These areas are discussed separately because there is only one large irrigation district in the entire area, thus non-survey data sources are used more extensively than elsewhere in the Report. In the case of the Upper Gila –Safford Valley, our survey of district managers includes a single response – the 23rd – received in early 2004, from The Gila Valley Irrigation District

In the case of the Sulphur Springs Valley, where irrigated agriculture completely relies on groundwater delivered from privately owned wells, we rely on data collected by a team of researchers from the Bureau of Applied Research in Anthropology, at the University of Arizona, and reported in a study entitled, "*Vulnerability to Climate Variability in the Farming Sector-A Case Study of Groundwater Dependent Agriculture in Southeastern Arizona*" . That work is summarized here. An electronic version can be found at http://www.ispe.arizona.edu/climas/pubs.html.

II. The Supply of Water to Arizona's Irrigated Agriculture

Sources of Supply

Irrigated agriculture in Arizona uses three primary sources of water. These are surface water from the Colorado River mainstem and CAP canal; surface water from other principal Arizona streams, of which the Gila, Salt-Verde, Agua Fria, and Santa Cruz River systems are the more important; and groundwater. State law also recognizes two other water sources, so called 'in-lieu' water and effluent. Physical in-lieu water derives from CAP and effluent. Effluent was a supply source in only two responding districts. Locally occurring precipitation is of relatively minor importance over most of Arizona's larger irrigation districts, but for districts relying on surface water, precipitation on often distant watersheds is the original water source.

Use of surface water depends on flow volumes – which vary annually – and is governed by priority of claim or permit, as detailed on page 15 of the Draft Operational Drought Plan of August 17, 2004. For those irrigating with surface water, vulnerability to drought in Arizona irrigated agriculture is importantly influenced by priority of use. In other words, the ability to irrigate with surface water would depend in large part on the volume of available water and on the priority rank of the user. Available volumes and priority rank are legal, institutional, physical, and hydrologic in nature.

Use of groundwater depends on location, specifically whether or not the use (point of diversion) is located within one of the State's five active management areas (AMA's). For those irrigating with groundwater at this writing, vulnerability to drought is related more to physical and hydrologic factors than to legal and institutional ones. There is discussion of groundwater management in Arizona on pages 13 – 15 of the 8/17/2004 Draft Operational Drought Plan.

So, the supply of water to those relying on irrigation district deliveries is mostly influenced by how many water sources are available to the district; water volumes available to the district by source; related surface water priorities; and related physical and hydrological limits on groundwater withdrawals.

Concerning individual growers, or groups of growers, who irrigate and are located inside of irrigation districts, some use only district supplies, some use both district supplies and their own individual wells, and some use only their own individual wells. When district supplies are curtailed, for example by drought, individual growers may replace district supplies by increasing their private groundwater withdrawals, to make a full complement of water.

An important amount of irrigated Arizona agriculture relies on groundwater withdrawn by individual growers, who may or may not also have access to irrigation district supplies. At this writing, in general, for those individual growers irrigating with groundwater withdrawn from their own wells, vulnerability to drought is primarily related to the same physical and hydrological limits faced by wells owned, leased, or operated by irrigation districts. Groundwater for irrigated agricultural use by individual pumpers is an important water source in Eastern and South Eastern Arizona, to a lesser but still important degree in Central Arizona, and to a small degree in Yuma and along the Colorado Mainstem.

Classification of Irrigation Districts by Sources of Supply and Geographic Location as Reported by Irrigation District Managers

The survey asked for the approximate number of acre feet the district delivered[1] to irrigated agriculture in years 2000 and 2001 (this survey section is reproduced in an Annex to Chapter II in the full Work Group Report). It then asked about what percentage of district supplies came from each of six sources during those baseline years and during 2003. Finally, the survey asked managers to look out a dozen years, and indicate how they thought district supply sources might change. The water supplies of interest were those of the irrigation district, not those of individual growers or groups of growers within the district. This survey information is presented on Table 1.

The survey permits a classification of irrigation districts by the number of water sources available to the district, by their geographic location, and by their baseline volumes delivered. The six water sources are: CAP; other Colorado River water (mainstem Colorado); non-CAP surface water; district groundwater; in-lieu; and other. These last two categories consist entirely of effluent or CAP surface water delivered in-lieu of groundwater pumping.

Responding Districts that Rely Solely on Colorado River Mainstem Surface Water with Priority[2] 1, 2, or 3 Rights

Four Yuma County irrigation districts in this category responded to our survey: Unit "B", Wellton-Mohawk, Yuma ID, and Yuma County Water Users Association. Together, the four delivered just under 750,000 acre feet (af) of irrigation water in both baseline years (Table 1). These four districts all enjoy senior water rights to their mainstem Colorado River water (in the full Work Group Report, see the Chapter II Annex by Don Pope). The senior rights greatly limit the vulnerability of these districts to hydrologic drought. Two more large Yuma County districts who did not respond to our survey are also hold senior Colorado River rights, as do several mainstem Colorado River Indian Tribes.

Responding Districts that Rely Entirely or Almost Entirely on CAP and In-Lieu Supplies – No District-Delivered Groundwater

[1]. Both the survey and the Work Group are concerned with water deliveries, not with consumptive use or some other measure of water volumes.

[2]. For a discussion of priorities to Colorado River and other surface water supplies, see the Background Document in the full Task Force Report.

IRRIGATION DISTRICT	CO.	'Normal' AF Delivered		Mainstem Colorado			CAP			In Lieu			Other Surface			District Groundw.			Other Sources			Total	
		2000	2001	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2003	'15	Normal	2015
Gila Valley Irrigation District	Gra	0	0																			0	0
McMullen Valley Irrigatio	LaP	0	0																			0	0
Harquahala Valley Irrigat	Mar	100497	93867				100	100														100	100
Hyder Valley Irrigation &	Mar	4	4													100	100	M				100	100
Maricopa Water District	Mar	60144	55257								40	L	60	40		40	20	M				100	100
New State Irrigation & D	Mar	907	527										71	50	L	29	50	L				100	100
Roosevelt Irrigation Dist	Mar	169063	166732													80	80		20	20		100	100
Salt River Project	Mar	152916	146278				14	10	L	19	22	L	45	29	M	22	39	L			M	100	100
San Tan Irrigation Distri	Mar	3525	2919													100	100					100	100
Tonopah Irrigation Distri	Mar	14514	15056				46	37	L	54	63	M										100	100
Paloma Irrigation & Drai	Mar	136936	138153											15	L		85	M				0	100
Roosevelt Water Conser	Mar	98043	98836							82	50	L			M	18	45	L	0	5	M	100	100
New Magma Irrigation &	M-P	92995	90603				47	53	L	53	47	L										100	100
Cortaro-Marana Irrigatio	Pim	35000	32000				8	8	L				50	50		42	42					100	100
Central Arizona Irrigatio	Pin	233167	221261				60	55	L							40	45	M				100	100
Hohokam Irrigation & Dr	Pin	75023	74027				30	54	M	70	46	L										100	100
Maricopa-Stanfield IDD	Pin	230333	242366				46	51	L	19	5	L				35	44	M				100	100
San Carlos Irrigation & D	Pin	39307	73378				7	12	M				60	18	M	33	70	L				100	100
Hilander "C" Irrigation &	Yum	0	0																			0	0
Unit "B" Irrigation & Drai	Yum	28606.1	26617.2	100	100																	100	100
Wellton-Mohawk Irrigati	Yum	400000	400000	100	100																	100	100
Yuma Irrigation District	Yum	62102	60036	100	100																	100	100
Yuma County Water Use	Yum	249432	238783	100	100																	100	100
Totals		**2182514.1**	**2176700.2**																			0	0

Table title: **TABLE 1: Statistical Information As Reported By Irrigation District Managers - Sources of Water in %**

Volumes delivered are in acre-feet. L = Less, M = More. The survey referred to the years 2000 & 2001 as 'normal' rather than baseline.

Notes on 'Other Surface' and 'Other Sources' :

MWD: Surface water from the Agua Fria system.
New State: Supplies delivered by SRP.
SRP: Surface water from the Salt-Verde system.
Paloma ID: Gila River water diverted at Gillespie Dam into the Gila Bend Canal; mostly 91st Ave. plant plus Buckeye IDD drainage. Paloma did not deliver water in 2000/01.
CMIDD: Water withdrawn from wells constitutes all CMIDD supplies, except for CAP water.
SCIDD: Surface Water from Gila system.
RID: Other would be the 23rd Ave plant.

Four irrigation districts in this category responded to our survey. Harquahala Valley IDD, Tonopah ID, New Magma IDD, and Hohokam IDD are all located in Maricopa and Pinal Counties. Together, these four delivered about 283,000 and 274,000 acre feet of irrigation water in the baseline years. These four districts (as opposed to their individual growers) are dependent solely on in-lieu[3] and CAP supplies (Table 1) with a junior priority[2]. In effect, these districts have no control over their water supplies, and are therefore among the most vulnerable districts to prolonged hydrologic drought on the Colorado River.

Most if not all individual growers (or groups of growers) in these districts have access to groundwater from privately owned wells. In some districts, total volumes delivered from privately-owned wells may exceed volumes delivered by the district. Under most circumstances, if individual growers experience reduced deliveries of CAP or in-lieu supplies, they will increase groundwater withdrawals, to deliver a full water supply.

Responding Districts that Rely on CAP Supplies (Including In-Lieu) and Also Deliver Groundwater

Central Arizona IDD, Maricopa-Stanfield IDD, and Roosevelt WCD responded to our survey. Together, they delivered about 562,000 acre feet of irrigation water in both baseline years. These districts can adjust the balance between surface and groundwater supplies. District groundwater is withdrawn from wells owned, operated, or leased by these districts (not individual growers or groups of growers). CAIDD and MSIDD balance groundwater and Junior CAP surface water, augmented (in the case of CAIDD) by some in-lieu water. RWCD combines in-lieu and groundwater. There are no grower-controlled wells in either CAIDD or MSIDD.

To deliver full supplies in 2003, these districts all increased groundwater withdrawals, as supplies to agriculture of CAP and in-lieu water decreased. Because of this ability to substitute groundwater for surface water, at least to some degree, these districts are somewhat less vulnerable than those districts relying solely on CAP and in-lieu supplies. However, reliance on increased groundwater withdrawals is associated with other vulnerabilities, discussed below.

Responding Districts that Rely on Non-CAP Surface Water and Also Deliver Groundwater

Five districts in this category responded to our survey. Maricopa WD, New State IDD, SRP, Cortaro-Marana ID, and San Carlos IDD are located in Maricopa, Pima, and Pinal Counties. Together they delivered about 288,300 and 307,440 acre feet of irrigation water in the baseline years. To varying degrees, these districts can balance surface and groundwater supplies. District groundwater is withdrawn from wells owned, operated, or leased by these districts (not individual growers or groups of growers). Most surface water comes from the Agua Fria, Verde, Salt, Santa Cruz, and Gila River systems augmented to a relatively minor degree by CAP (including in-lieu).

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[3]. In-lieu supplies derive from either CAP or effluent.

Because of a greater relative balance in their water sources, these districts are generally somewhat less vulnerable to long-term hydrologic drought than those relying exclusively on CAP supplies, but more vulnerable than the high priority mainstem Colorado River districts. Recent widely fluctuating surface water supplies have increased the vulnerability to long-term hydrologic drought in several of these districts.

Individual growers (or groups of growers) who experience reduced district deliveries may also have access to groundwater from privately owned wells and may increase private groundwater withdrawals. In 2003, this did occur, as a result of highly fluctuating surface water supplies in principal Arizona streams.

Responding Districts That Rely on Groundwater for at Least 80% of Supplies

Six responding districts rely on groundwater for 80 to 100% of their irrigation water supplies. McMullen Valley IDD, Hyder Valley Irrigation and Water Delivery District, Hilander 'C' IDD, Roosevelt ID, Paloma IDD, and San Tan ID are geographically dispersed throughout Maricopa, La Paz, and Yuma Counties. Together, these six delivered about 309,500 and 307,800 acre feet of irrigation water in the baseline years. Hilander 'C' and McMullen Valley IDD do not deliver water, rather growers there irrigate with water withdrawn from their own privately owned wells. Hyder Valley is very small, delivering just four acre feet of water in each of the baseline years of 2000 and 2001.

Approximately 80% of RID's water supply is withdrawn from district-owned wells. The remaining 20% is 'other' water, in this case effluent from the 23rd Avenue plant. Approximately 85% of Paloma IDD's water supply is withdrawn from district-owned wells. The remaining 15% is Gila River surface water diverted into the Gila Bend Canal at Gillespie Dam. The source of this surface water is effluent from the 91st Avenue plant and may include Buckeye WCDD drainage. The ability of these districts to substitute between water sources is limited by their high reliance on groundwater. The vulnerability of these districts, and the growers within them who also irrigate with privately-owned wells, will depend on physical and hydrologic factors, such as well yield, depth to water, and volumes available for withdrawal.

Eastern and South Eastern Arizona

The Gila Valley Irrigation District (GVID) encompasses about 35,500 acres, most of which are cropped annually. The GVID does not deliver water, but represents ten different canal companies within the District. The canal companies deliver water to farmers who also irrigate with privately owned wells. Some canal companies also own wells. Surface water rights in the Safford area are authorized through the Gila River Decree. Gila River surface water is allocated to the canal companies in accordance with the Decree. During most of the preceding five years, little or no Gila River surface water has been allotted, therefore, virtually all recent irrigated agriculture in the Safford valley has relied on groundwater, whether withdrawn from individually-owned wells, or by the canal companies.

The Sulphur Springs Valley encompasses approximately 60,000 acres and includes agricultural areas south of the Safford Valley, including the Bonita area and Willcox to Douglas. The region has no permanent sources of surface water, thus the development of irrigated agriculture has completely relied on groundwater from the Willcox and Douglas basins. The Willcox basin occupies the northern three-fifths of the valley and covers approximately 1,911 square miles. It is the largest source of groundwater with an estimated 45.3 million acre feet of groundwater stored to 1,2000 feet (ADWR 1994b). Within this basin the average well depth is 450 feet, but depths may vary from 100 feet in relatively shallow aquifers up to 700 feet in such areas as Kansas Settlement (Clark and Dunn 1997). The Douglas basin occupies the southern two-fifths of the valley and contains approximately 750 square miles. It has an estimated 32 million acre feet of groundwater stored at 1,200 feet (ADWR 1994a). The principal source of groundwater recharge for the basins is winter precipitation, including snowmelt from the surrounding mountain ranges, which is transported to the valley by streams and washes (Mann et al. 1978).

Trends in Sources of Irrigation Water Supplies

The survey – and our other data sources – allow an assessment of two types of trends:

- Did supply sources change in 2003, as compared to the 2000-2001 baseline; and
- Do managers anticipate that supply sources are likely to change over the next dozen years?

Effect of Drought: Changing Supply Sources in 2003 – Increasing Agricultural Reliance on Groundwater

Among the eight responding districts relying on balance between surface and groundwater, our responding district managers reported a clear trend toward increased reliance on groundwater and decreased reliance on renewable surface water supplies in 2003. (Table 1 – SRP, RWCD, CAIDD, MSIDD, SCIDD, and New State). This trend was prompted by increasing demands on and reduced availability of surface water supplies, as a direct result of drought.

Anticipated Changes in Agricultural Water Sources towards 2015 – Increased Reliance on Groundwater

Looking at the '2015' columns on Table 1, responding district managers expect greatly reduced reliance on CAP and in-lieu supplies by that time. The responding managers expect to pump more groundwater to replace those surface supplies. The only districts anticipating less reliance on groundwater by 2015 – SCIDD, RWCD, SRP, and New State – have already reduced surface water deliveries and increased groundwater withdrawals because of drought. By 2015, these districts may be expecting a return to baseline surface flows, which would allow them to pump less groundwater.

A Note on Groundwater Withdrawals and the Vulnerability of Irrigated Agriculture to Long-Term Drought

Wells are an important source of water to Arizona's irrigated agriculture and can provide some insulation against shortages caused by drought. At the same time, long-term drought may expose irrigators using groundwater to increased vulnerability from several sources. Water tables may decline. This may affect well yield, and will increase the cost of pumping as more electricity will be required to lift the same amount of water. Quality often worsens as deeper water is withdrawn. Drought has already affected the quantity of electricity generated and this threatens to reduce power supplies and increase power costs at the same time as more electricity is required. Some wells may have been idle or infrequently used for long periods of time. Experience shows that such wells may require often costly rehabilitation before they again become fully productive. Finally, in most districts, it is physically impossible to serve all district lands from every well.

III. The Vulnerability Of Arizona Irrigated Agriculture To Long-Term Drought

Summary of Results – District Manager Survey

The survey listed eighteen circumstances that might make the irrigation district vulnerable to drought, either in the current 2003 situation or if the drought were to deepen into 2005 or 2006. Table 2 summarizes the results.

Table 2. Summary of Survey Results – Vulnerability Circumstances

Absolute Rank *by total number indicating in 2003 and 2005/06*: Vulnerability Circumstance *(n = 22[1])*	2003: How many mgrs. *(no.[2])*	2003: How much water *(maf[3])*	2005/06: How many mgrs. *(no.[2])*	2005/06: How much water *(maf[3])*	Delta Rank *by number in 2005/06 minus number in 2003*: Vulnerability Circumstance *(n = 22[1])*	Delta *(no.[2])*	How much water *(maf[3])*
Single water source	8	1026	12	1553	Severe supply shortage	7	759
Lack of/inadequate storage	7	777	8	915	Lack of preparedness	5	517
Wide precip. variation	7	440	8	783	Single water source	4	527
High growth affecting supply	6	541	6	582	Sudden change in supply	4	483
Low priority water rights	4	417	6	728	Low water supply reliability	3	304
Low water supply reliability	4	212	7	516	Imported water supply	3	
Sudden change in supply	3	264	7	747	Uncertain/low power supply	3	265
No political will to act	3		2		Low priority water rights	2	311
Uncertain/low power supply	2	85.3	5	350			
Severe supply shortage	1	56.3	8	815			
Lack of planning/preparedn's	1	27.6	6	545			

1. All 22 responding managers indicated one or more vulnerability circumstances.
2. The number of managers who indicated the circumstance.
3. Thousand acre feet delivered by the districts during the baseline period, (2001 + 2002)/2.

These results[4] are used to discuss three questions:

1. In 2003, which were the more important irrigation district drought vulnerabilities, in terms of both the absolute number of districts and the volumes of water delivered? How did this vary by geographic location, sources of water, and priorities over water use?

2. Which vulnerabilities might irrigation districts be most exposed to if the current drought continues into 2005 or 2006?

3. Are trends in the vulnerabilities of irrigation districts to drought evident between 2003 and 2005/06, assuming the current drought continues?

Irrigation District Vulnerability To Drought in 2003

Looking at drought during 2003, vulnerability to a ***single water source*** was the most frequently experienced drought vulnerability and cut across all counties, water sources, and surface water priorities responding. Referring to Table 1, it is noteworthy that 9 of the 22 responding districts relied on a single source for all of their irrigation water, and three more districts relied on one source for at least 80% of their supplies.

In 2003, a tie for second occurred among two characteristics: Lack of or inadequate ***water storage***, and ***widely varying precipitation***. The concern over ***storage*** was more concentrated among district managers relying on the Colorado River (including CAP users), perhaps reflecting current reservoir levels in Lakes Mead and Powell. Concern with ***widely varying precipitation*** seemed of greatest concern among districts who depend significantly on surface water supplies, including those using all of Arizona's principal streams. Locally occurring precipitation is of relatively minor importance over most of Arizona's more important irrigation districts, but for districts relying on surface water, precipitation on often distant watersheds is the original water source.

Vulnerability ***to high additional demand*** resulting from high growth was the fourth-most frequent vulnerability circumstance mentioned, and this vulnerability was more concentrated among districts located on the urban fringes of Yuma, the southeast and southwest Phoenix valley, and north Tucson.

Tied for the fifth-most frequent 2003 vulnerability were two more characteristics: ***low water supply reliability***, and ***low priority water/contractual rights***. The concern over ***low reliability*** was evident among districts that use widely fluctuating surface water supplies and junior non-Indian agricultural pool CAP users. In 2003, ***low priority rights*** were of concern in districts relying extensively on junior CAP rights.

Irrigation District Vulnerability if the Present Drought Continues Into 2005 or 2006

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[4]. The one survey from eastern and south eastern Arizona is not included here, but is discussed separately at the end of this chapter.

Vulnerability concerns by 2005/06 were similar to 2003, but district managers did signal several new concerns and, in general, expected exposure to a greater number of vulnerabilities if the drought continues.

Vulnerability to a ***single source*** of supply continued of greatest concern across all geographic locations, sources of water, and surface water priorities. When combined with the statistical information related to trends anticipated in 2015 (Table 1), we can see that the prospect of a prolonged drought is causing district managers to anticipate a decreased reliance on surface water and an increased reliance on groundwater.

The prospects of a ***severe supply shortage***, lack of or inadequate ***water storage***, and ***widely varying precipitation*** tied as the second highest concerns if the present drought were to continue into 2005/06. Concern that a ***severe supply shortage*** might develop by 2005/06 was spread across geographic areas, water sources, and surface water right priorities, but was not among the leading vulnerability characteristics mentioned by district managers in 2003. Concern about ***storage*** was more concentrated among responding senior and junior Colorado River users. Districts concerned about ***widely varying precipitation*** included those using all of Arizona's principal streams: the Colorado (whether senior or junior right holders), Agua Fria, Salt-Verde, Gila, and Santa Cruz Rivers.

Anticipated Trends between 2003 and 2005 or 2006, if the Drought Continues

The increase in concern over a potential ***severe shortage*** – from one to eight district managers – was the largest increase in concern with any drought vulnerability characteristic and was spread across geographic areas, water sources, and surface water right priorities. About two in five district managers may anticipate their water supply situations to seriously worsen if the current drought were to continue for even two or three more years.

The increase in concern over a lack of ***drought planning and preparedness*** that may develop over the 2003 to 2005/06 period – from one to six district managers – was the second-largest increase in concern with any drought vulnerability characteristic. This concern was spread across geographic areas; districts relying on groundwater, the Colorado and other surface water sources; both junior and senior right-holders; and volumes delivered. One interpretation of this information might be that more than one in four of our responding district managers attach importance to advance early warning: They would like to see a developing problem coming as far in advance as possible. Because a number of districts already have – and indeed, are implementing – contingency plans for dealing with district-level supply shortages, a second interpretation might be support for Statewide drought planning.

Concerns over dependence on ***single supply*** sources tied for the third-largest vulnerability trend. To the degree that this trend may also be associated with a decreased reliance on surface water and an increased reliance on groundwater, the set of specific vulnerability circumstances may change but overall vulnerability may further increase.

Vulnerability to ***sudden changes in supply*** was the other third place trend. CAP users experienced intensifying competition for water in 2003, and may be anticipating more of the same if the drought continues. This would lead to increasing vulnerability, the more so if the availability of other surface sources continues to diminish.

By 2005/06, ***Power supplies*** may become less certain and power supplies may fall. At the same time, power demand and unit power costs both may rise. These eventualities are likely to increase the total expenditure on power, whether at district or individual grower level.

Eastern and South Eastern Arizona

According to the manager of the Gila Valley Irrigation District, water supplies to irrigated agriculture in the Safford area are vulnerable to low reliability, sudden changes, periodic severe shortages, and contamination, and all of these factors are in turn related to natural disasters such as flooding and widely varying precipitation. Other vulnerability circumstances in the Upper Gila Valley area include a lack of drought forecasting, planning, preparedness, and data and low priority water/contractual rights. The District Manager noted only one trend if the drought continues, increasing reliance on groundwater as the single water source. A number of irrigation wells in the Valley are relatively shallow. The service areas for shallow wells are expected to become more reliant on surface diversions as groundwater levels decline with continuing drought. However, surface diversions have been mostly unavailable during recent years.

Since the 1970s, groundwater overdraft has been a major concern throughout the Sulphur Springs Valley region as more groundwater is being pumped than recharged. With long-term drought, water levels decline and the price of energy increases, the cost of groundwater irrigation goes up, and with it the vulnerability of irrigated agriculture. Given the present drought, access to water presents perhaps the greatest challenge to the local farming industry, and those whose crops require more water tend to be more vulnerable. As drought lowers the water table, knowing if the dry winters will continue is the most important factor in deciding whether to continue farming.

Vulnerability to drought, however, is not only related to hydrologic and climatic conditions. Farmers rely on both vertical (institutional) and horizontal (social capital) networks to reduce their vulnerability. These formal and informal networks provide access to climate information and to financial and other assets that allow farmers to respond to drought and adapt. Farmers under disadvantaged socioeconomic conditions have a more difficult time recovering from and adapting to drought.

Discussion and Recommendations for Drought Planning: Water Supply and Drought Vulnerability Options

If correlated with geography to a degree, water supply to Arizona's irrigated agriculture is more a function of the number of water sources available at a specific location, the volumes available from each source, priority rights and claims, and physical and hydrologic limits on groundwater withdrawals including access to groundwater, its quality, volumes available, and the ability to deliver it locally. Geographic distance or time often separate the origin of irrigation water from its place of use. The vulnerability of irrigated agriculture water supplies during drought is directly related to these variables, and drought preparedness involving irrigated agriculture must recognize diversity across irrigation districts with respect to them.

Keeping these caveats in mind, one approach to drought management and longer-term drought planning and preparedness is to focus on the more important and tractable supply vulnerabilities revealed by the Irrigated Agriculture Work Group.

Vulnerability resulting from the number of water sources available at a particular location and the physical and hydrological limits on groundwater withdrawals can be amenable to strategic intervention. For example, wheeling, increasing inter-connectivity, or facilitating willing and voluntary market-based trades where applicable are options for diversifying water sources. Likewise, facilitating well rehabilitation and improving the ability of wells to command larger areas are options to help relax physical and hydrologic constraints on groundwater withdrawals, again where applicable.

Looking at specific circumstances, the Working Group was concerned first and foremost with reliance on single sources of supply, both now and over the next two or three years. The options mentioned in the previous paragraph – wheeling, increasing connectivity, or voluntary market-based trades – might address single supply concerns, as well as such other vulnerabilities as low supply reliability or sudden and severe shortages.

A lack of or inadequate storage was also a chief concern, and the Working Group notes that large impoundment projects are not the only way to address this problem. Small local regulatory storages and recharge projects are being used effectively at several Arizona locations. Irrigation districts use sumps, ditches, or ponds to capture and reuse tail water.

Concern over uncertain or low-priority power supplies has intensified during 2004. Any measures that will help rural power districts tie down long-term power supplies are likely to be increasingly important to Arizona's irrigated agriculture.

Arizona's vulnerability to a statewide lack of drought planning and preparedness will be alleviated considerably when the Operational Drought Plan is finalized. Monitoring, data and triggers, local area impact assessment groups, and interagency coordination address Work Group concerns. Increased emphasis on longer-range, location specific weather forecasting would address agricultural vulnerabilities in irrigated areas that rely heavily on shallow, precip-recharged aquifers, such as Eastern and South Eastern Arizona.

IV. Impacts

Summary of Results – District Manager Survey

The statewide survey of irrigation district managers listed seventeen drought impact statements (Chapter IV Survey Section Annex, full Work Group Report), and asked the following question:

> "Below are several statements regarding the possible impacts across the *DISTRICT* of the current drought. Please circle the number that best describes your opinion about how the current drought might impact conditions in the *DISTRICT*, assuming water supply does not improve over the next year or two. Considering the statement, is the drought likely to cause:
> 1 = Minor or no impact;
> 2 = Some impact;
> 3 = Significant impact."

Table 3: Summary of Results – Long-Term Drought Impacts
Top and Bottom Five Statements, Ranked by Total Score[5]

Top Five Statements *(by total score)*	Total Score	No. '3's	Bottom Five Statements *(by total score)*	Total Score	No. '1's
Increased GW depletion/w. table decline	47	11	Air quality effects/PM-10 problems	24	15
Increased energy demand/reduced supply	41	7	Insect, disease, pest infestation	27	13
Income loss – farmers and the District	41	7	Decreased land prices in the District	27	14
Fewer planted acres in the District	38	6	Cost of water transportation	29	11
Financial viability of the District	37	5	Water quality effects	32	10
Reservoir and lake drawdown	37	7			

All twenty-two managers[6] responded to at least one of seventeen statements. The Work Group divided the 17 impact statements into four categories:

- ✓ Supply depletion and other environmental concerns
- ✓ Other impacts – energy demand and supply
- ✓ Financial viability, income loss, and land prices
- ✓ Agronomic impacts: Planted acres, crop quality, land productivity, pest infestation, and yield declines

Water Supply Depletion

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[5]. The scoring system is explained in the full Work Group Report.

[6]. Again, the 23rd survey, from GVID, is discussed separately, on page 19.

If water supplies in responding districts do not improve over the next year or two, the responding managers expect impact from groundwater depletion, water table declines, and reservoir and lake drawdown (full Work Group Report, Chapter III Summary Table). Impacts from groundwater depletion and water table declines are expected throughout Maricopa, Pinal, and Pima Counties. Supply sources in concerned districts include groundwater, surface water from principal Arizona streams, and CAP. Several districts concerned about depletion rely on more than one source of supply. Looking at reservoir and lake drawdown, seven districts expected significant impact and those districts represented all surveyed areas, all priority classes, and all water sources. Again, districts that rely on several water sources were concerned about reservoir and lake drawdown.

Energy Demand and Supply

By the summer of 2004, drought had already impacted energy demand and supply in several responding districts. If water supplies do not improve over the next year or two, the responding managers expect these impacts to intensify, with several central Arizona districts indicating "significant impact". Increasing demand for and reduced supplies of power can combine to raise unit power costs and increase total power expenditures, whether at district or individual grower level. The pronounced move to groundwater has increased energy demand and raised power expenditures among well-operators, both individual and district. Power is supplied to many irrigators under fixed-price, long-term contracts. As these expire and are renegotiated in the current environment, those prices will rise. Power shortages feed-back to constrain water supply, while increased power expenditures exacerbate negative effects on income and financial viability.

Income Loss and Financial Viability

If water supplies in responding districts do not improve over the next year or two, the responding managers expect income losses to both farmers and the district and adverse impacts on the financial viability of irrigation districts. Secondary economic impacts – ripple effects – in the form of economic loss to secondary business and commerce dependant on primary agricultural production were also concerns several managers. To the degree that reduced water supplies translate into idled cropland, yield or quality declines, increased pest problems, increased costs, and the like, on-farm income is likely to be lost. These same effects can impact the financial viability of irrigation districts, because delivery volumes translate into a principal revenue stream of many districts – i.e., per acre-foot water charges. When delivered supplies fall, district revenues also fall. This has led some districts to increase per acre assessments, which translates back to decreased on-farm income. Employment at districts, on-farms, and in other agriculturally dependant commerce can be negatively impacted in these circumstances.

Planted Acres

If water supplies in responding districts do not improve over the next year or two, the surveyed managers expect impact from fewer planted acres, in other words, drought will cause the number of acres in production to decline. Anecdotal information provided by three managers indicates that, in fact in 2003, drought idled thousands of acres in those three districts, an impact that can be expected to worsen and spread if the drought persists into 2004 and 2005 (See SCIDD Annex to Chapter III in the full Work Group Report). This land idling was caused by drought-induced reduced stream flow, combined with junior claims that could not be compensated from other sources, such as wells.

Drought Impacts on Arizona's Dairies and Feed Yards

An extended drought could impact how and where Arizona's dairies and feed yards find and produce their water supplies (See the "Dairies and Feed Yards" Annex to Chapter II in the full Work Group Report). Any interruption of production – whether on animals being fed or to the production of grain and forage that supply the livestock feeding industry – due to declining or intermittent water supplies will be associated with severe economic impacts to Arizona's dairies and feed yards. A decline in feed quality caused by water shortage will have similar negative economic impacts. Any drought-induced lengthening of the feed supply chain (reliance on more distant feed) also implies increased cost to the industry.

Eastern and South Eastern Arizona

Sources in the Upper Gila – Safford Valley area report that declining groundwater tables have caused shallower wells to surge and well yields to decline, while surface water allocations from the Gila River have been at or near zero for several years. Planted acres have been cut back. The GVID survey notes significant negative impacts in all of the survey summary categories. Water supplies are depleting. Energy demand is increasing while supplies are declining or being curtailed. There has been income loss for farmers and the ditch companies, as well as economic loss to secondary business and commerce directly dependent on primary agricultural production.

Overdraft and declining water tables have been a chief concern in the Sulphur Springs Valley (SSV) since before the 1970's. Under conditions of long-term drought, access to water becomes the principal limiting factor for agriculture in the region. Access is largely determined by the depth from which water has to be pumped and the costs of pumping it. Meanwhile, the SSV is subject to the same drought impacts on power demand and supply experienced elsewhere in Arizona and the southwest. So, drought in the SSV tends to increase the depth to water and pumping costs. These associate with increased water supply uncertainty and increased costs to farm. During the 1970's, declining water tables caused a large percentage of farms in the SSV to go out of business.

Discussion and Recommendations for Planning: Drought Impacts and How They Relate To Vulnerabilities

While it may be appropriate to target short-term drought response at drought impacts, longer-term drought preparedness might more effectively target vulnerabilities. In general, it appears that managers from those districts relying on a combination of groundwater from either district or individual grower wells plus Junior CAP supplies (including in-lieu) were **more likely to indicate 'significant impacts'** on the survey.

Several of trends discerned in Chapter II are about to translate into, and in some areas have already translated into, **income loss for farmers and districts** and adverse impacts on the **financial viability of districts**. Fewer planted acres is one source of income loss and decreased financial viability. From Chapter III, related vulnerabilities of note include severe supply shortages, sudden supply changes, low water supply reliability, and uncertain or low priority power supplies. Longer-term, focus on these vulnerabilities will probably better prepare irrigated agriculture for drought. Related preparedness options were recommended on page 18.

Reported **supply depletion** impacts appear to reinforce Chapter III discussion about a seriously worsening supply situation if the drought continues to deepen for even two or three more years. The impacts associated with reservoir and lake drawdown translate into an increased reliance on and use of groundwater, which associate in-turn with increased groundwater depletion and water table declines. In terms of Chapter III vulnerabilities, **supply depletion** impacts can be associated with lack of and inadequate storage, wide precipitation variation on watersheds, and low water supply reliability. Looking at trends, it seems clear that drought and other recent supply effects are impacting groundwater supplies in Arizona. **Supply depletion** may translate into higher production costs and fewer planted acres. Reader attention is again drawn to the page 18 discussion of preparedness options related to low reliability, shortages, and storage.

Impacts from **increased power demand and reduced supply** also appear related to vulnerability trends noted in Chapter III. One trend is the increasing drought-induced reliance on groundwater, which may cause static water tables to fall and lifts to increase. The second trend is drought-induced exposure to uncertain or low priority power supplies. A net effect was noted, that power demand and unit costs both may rise at the same time as power supply may be diminishing. This increases total power expenditures, whether at district or individual grower level, in-turn increasing district and grower financial vulnerability.

In 2003, **fewer planted acres** in three affected districts were associated with vulnerabilities related to uncertain or unreliable supplies, wide precipitation variation on watersheds, dependence on single sources, and inadequate storage.

V. Response, Adaptation, and Preparedness

Summary of Results – District Manager Survey

The statewide survey of irrigation district managers listed twenty-seven drought preparedness and response items (Annex to Chapter V, full Work Group Report). The Work Group distinguished between drought preparedness and response. *Preparedness* is action taken in advance of an impending drought. It is proactive and adaptive, designed to lessen the vulnerability to and the impact of future drought. By contrast, *Response* refers more to dealing with an existing or imminent drought situation. It is reactive, aimed at mitigating drought effects about to be or already being experienced.

Looking at the 27 items individually, the following, in order, had the highest percentage of ***positive*** district manager responses[7]:

Preparedness and Response Item	Positive (%)
Create drought property tax credit program for farmers	83
Guaranteed low-interest loans to drought-stricken farmers	83
Short-term, voluntary, market-driven water transfers	79
Investment program: Increase flexibility of water supply sources	78
Develop a State water plan	75
Develop criteria to trigger drought-related actions	65
Improve accuracy of seasonal runoff and water supply forecasts	65

Looking at the 27 items individually, the following, in order, had the highest percentage of ***negative*** district manager responses[8]:

Preparedness and Response Item	Negative (%)
Five physical conservation practices[a]	76
Four management conservation practices[a]	69
Establish new data collection networks	65
Study effectiveness of water conservation measures	65

a. Most respondents said these were already available.

The Work Group divided the 27 items into these five categories:

- ✓ Forecasting and early warning
- ✓ Programs
- ✓ Agricultural water conservation

[7]. A *positive* response was an affirmative answer that the item either "might help some," or was "potentially very important."
[8]. A *negative* response was an affirmative answer that the item was either "already available," or, "would not help."

- ✓ Voluntary, market-driven water transfers
- ✓ Planning and research

On a category basis, the breakdown between positive responses – either "might help some", or "potentially very important" – and negative responses – either "already available" or "would not help" – was:

Item Categories	Positive (%)	Negative (%)
Voluntary, market-driven water transfers	79	21
Programs *(4 items)*	78	22
Planning and Research *(4 items)*	58	42
Forecasting and early warning *(5 items)*	54	46
Agricultural water conservation *(13 items)*	35	65

Eastern and South Eastern Arizona

GVID sources indicated that all 27 drought preparedness and response items from the survey either might help some or were potentially very important. The GVID district manager indicated that the more important items included developing drought triggers, early warning systems (long-range forecasts), and a statewide water plan. Drought property tax credits and guaranteed low-interest loans for drought-stricken farmers were also potentially very important. Promising conservation measures included canal lining, underground pipelines, and irrigation scheduling by crop water demand.

In the Upper Gila Valley – Safford area, because of the institutional organization of water rights, there may be little incentive to conserve water, in that any water saved by one simply becomes available for use by another, without compensation. Also, there was a need to reconcile agricultural with environmental issues: Measures such as canal lining might conflict with environmental rules and regulations.

As an agricultural region dependant on groundwater for irrigation, the Sulphur Springs Valley (SSV) provides insights into both the vulnerability of Arizona's irrigated agriculture and the adaptation strategies that may contribute to the long-term economic viability of irrigated agriculture in a semiarid environment where access to water is decreasing. Large-scale commercial agriculture became possible in the Sulphur Spring Valley with the establishment of the Sulphur Springs Valley Electrical Cooperative in the 1940s. Inexpensive energy to power electric pumps for irrigation, plus increased demand for cotton during World War II, led to a farming boom, attracting farmers to the SSV to produce mainly cotton and corn. Agricultural acreage expanded rapidly until 1976 when irrigated acreage reached a peak of 160,000 acres. But, annual water withdrawal began to exceed recharge in the late 1960s and static water depths began to drop. Droughts between 1973 and 1980 exacerbated the problem to the point that, in 1980, part of the region was declared as an Irrigation Non-Expansion Area and no new Irrigation Acres were allowed. The energy crisis of 1976 led to an exorbitant increase in the price of natural gas. In combination, these climatic and economic events drove farming families out of the region and, in the course of a few years, irrigated acreage declined by more than 66 percent, the largest decline of any agricultural region in Arizona.

Adaptation in the Sulpher Springs Valley

In the Sulphur Springs Valley, farmers expect and have adapted to a great deal of climatic variability from one year or season to the next and are concerned about climate variation that might affect the water table. Because farmers perceive that winter precipitation is the main source of aquifer recharge, they want winter precipitation forecasts that extend two to five years into the future. This knowledge would have direct relevance on decisions to deepen wells, to continue improving the efficiency of irrigation technology, to change cropping strategies, or perhaps to leave farming.

The repeated water supply crises in the SSV have prompted adaptations that include changes in irrigation technology and crop diversification in response to market signals. An important adaptation to low and erratic precipitation has been the adoption of more water efficient irrigation technologies. By the beginning of the 1990s, most larger farmers had replaced older flood furrow irrigation systems with newer center pivots, sprinklers, and drip irrigation.

Crop diversification has also been an important adaptation. Some abandoned fields were changed to fruit, pecan, and pistachio orchards. Other parcels were converted to food-grade corn, chile, lettuce, and a wide variety of other vegetables. Those who continue to grow traditional row crops such as corn, sorghum, cotton, and alfalfa generally do it in combination with other crops. High water costs have caused other farmers to target niche markets such as those for organic fruits and vegetables.

Public policy has played an important role in facilitating these changes. Since the 1940s, farmers have benefited substantially from a variety of federal commodity programs. More recently, the Environmental Quality Improvement Program – EQIP – and other Federal and State programs have provided farmer incentives to adopt water efficient irrigation technologies. Crop insurance, including prevented planting insurance, is becoming increasingly important in allowing farmers to recuperate from extreme events.

All of these adaptation strategies have allowed SSV growers to become better prepared to deal with future extreme climatic and economic conditions, but their adoption has not been uniform. Smaller farmers – those cultivating smaller plots of land – have been less capable of adopting new technologies or diversifying crop production and are more vulnerable to climatic extremes.

Discussion and Recommendations for Drought Planning: Preparedness and Response Options and How They Relate To Vulnerability and Impact in Arizona's Irrigated Agriculture

The information about preparedness and response can be interpreted in light of the analyses of drought vulnerabilities and impacts presented in previous chapters. The idea of voluntary, willing, term-limited, and **market-driven water transfers** received positive responses of "might help some", or "potentially very important", from fifteen of nineteen (79%) responding district managers. Voluntary and market-driven water transfers offer one means of preparing for or responding to several of Arizona's chief drought vulnerabilities, such as reliance on single supplies, inadequate storage, a threat of severe shortages, or sudden supply changes. Voluntary and market-driven water transfers further offer an approach to relieving such drought impacts as supply depletion, drawdown, and income loss to both farmers and irrigation districts. Experience elsewhere in the West shows that all parties to a successful transfer can and must benefit. Great care will be required if this avenue is explored as a drought preparedness or response item. But, over a longer-time, a term-limited and voluntary market approach may offer great promise to Arizona as a drought preparedness tool.

Programs received positive responses from 78% of the district managers. All individual program items included on the survey were popular with the responding district managers. Programs can be used to respond to an existing drought or to prepare for a long-term drought eventuality. Looking at specific program items, property tax credits and low-interest loans received the highest percentage of positive responses, followed by any type of investment program that would increase the flexibility of water supply sources. Any such programs could address the shortage, storage, or supply vulnerabilities reported in Chapter III.

Specifically, these types of **programs** could be used to improve on-farm or district distribution systems, or to increase well command areas. They could be used to promote system inter-connectivity or to add small regulatory storages. They could link to the conservation ideas discussed below, in fact, analogous types of programs are presently in use in some Federal and State incentive conservation programs. Such programs can further act to lessen the income and financial impacts reported in Chapter IV.

Looking at the items dealing with both **planning and research** and **forecasting and early warning**, the mildly positive response to these items can be evaluated in the context of those vulnerability circumstances of greatest concern to district managers: Single sources, widely varying precipitation, low water supply reliability, sudden water supply changes, the threat of severe shortages, and especially a current lack of drought planning and preparedness. One interpretation is that district managers would like to see any supply problems developing as far in advance as possible, which may reflect the trend noted, namely that supply problems already existed in 2003 and have become worse in 2004. In the forecasting and early warning category, developing criteria to trigger drought-related actions and improving the accuracy of seasonal runoff and water supply forecasts received the most positive responses from the district managers. These items are addressed in the draft Statewide Operational Drought Plan.

Our statewide survey of irrigation district managers listed thirteen **agricultural water conservation** drought preparedness and response items. Overall, 65% of the responding managers said the list of thirteen items were either already available or would not help. An even higher negative response was observed to the nine physical or management conservation items listed on the survey. The Irrigated Agriculture Work Group suggests that these results should be interpreted against the backdrop of the enormous statewide conservation investments that have already been made by Arizona's irrigated agriculture at both district and on-farm levels. Conservation incentive programs have been in place over many years in most of Arizona's irrigation districts. Many district managers may see limited conservation potential in management-type approaches, perhaps reflecting a view that the performance of most growers is already high in this area. The Work Group suggests that the most promising approaches to continued agricultural water conservation might include:

- ✓ Continued participation, on a voluntary basis, in existing incentive programs directed at physical and structural conservation improvements, targeting growers who may still benefit from voluntary participation in such programs;
- ✓ Continued participation, also on a voluntary basis, in agronomic and water management outreach programs, again directed at growers who volunteer to participate;
- ✓ Continued use of tax credits, low-interest loans, crop insurance, and like programs targeted at drought preparedness, along the lines of several existing programs already popular with Arizona growers.

Water conservation in Arizona's irrigated agriculture is discussed in detail in Chapter IV of the Full Work Group Report.

A Caveat About the Increasing Reliance on Groundwater

The present reversion to groundwater as a primary irrigated agriculture supply source cannot be an effective or even workable drought management strategy over a longer-term, for the same reasons that led to the 1980 Groundwater Code. Water tables will decline, affecting well yield and increasing the cost of pumping. Quality is likely to worsen as deeper water is withdrawn. Drought has already affected electricity generation and this threatens to reduce power supplies and increase power costs at the same time as electricity demand increases.

Institutional Context Restraining Drought Adaptation and Response

Eligibility requirements for popular Federal and State programs currently place restraints on certain types of drought response, for example land idling. Eligibility for the Environmental Quality Improvement Program (EQIP) requires the land placed under contract to have been farmed during at least two of the prior five years. Each time Federal commodity programs are renewed, 'base acre' provisions are usually attached. These constrain eligible program acreage to have been planted to specific commodities during a certain number of immediately preceding years. Financially, owner-operators cannot generally simply opt-out of farming when faced with difficulties such as drought. The same may be true of lessees with high fixed costs, such as machinery and equipment amortization requirements.